(12) EUROPEAN PATENT APPLICATION

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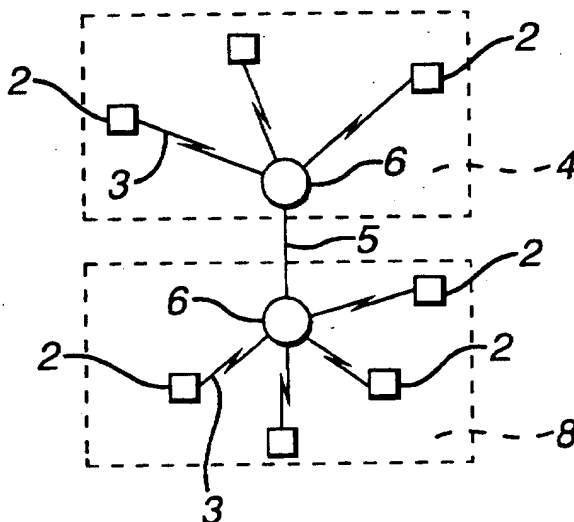Page White & Farrer,
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(54) Method and device for robust fallback in data communication systems

(57) Method and device for communicating at least one packet of data (11) with a predetermined packet size over a communication channel (3) from a transmitter (2; 6) to a receiver, the transmitter (2; 6) having a memory (21) for storing a common set of data rates, the method comprising the steps of fragmenting the at least one packet into a number of frames with a predetermined frame size by the transmitter (2; 6), automatically selecting a combination of frame size and one of the common set of data rates by the transmitter (2; 6) such that the transmission time of each of the frames is limited to a predefined value, and transmitting each frame over the communication channel (3) by the transmitter (2; 6).

FIG. 1a

Description

[0001] The present invention relates to a method for data communication between devices able to operate at various data rates, and more specifically relates to a method for providing a robust fallback facility for environments in which periodic or intermittent interference occurs.

[0002] Non-prepublished European patent application 99302624.2, filed by applicant of the present patent application, discloses a method for enhanced data rate control for wireless data communication. The method selects a data rate for a communication channel between first and second devices having a set of common data rates by selecting an initial data rate from the set and adjusting the data rate responsive to a change in channel conditions. This method provides an auto rate control mechanism which can determine the best usable data rate for a given channel condition. The selection of an increase or decrease in data rate can be based on whether a packet is transmitted successfully or unsuccessfully, respectively.

[0003] In certain environments, e.g. the 2.4-2.5 GHz industrial, scientific and medical (ISM) band used in wireless LAN communication, the operation of radio systems for data communication in this band can be subject to interference by radio systems and unintentional radiators. In the ISM band radio systems such as RF ID (radio frequency identification tag and labelling) systems and Bluetooth systems operate, and unintentional radiators covering the ISM band may be e.g. microwave ovens.

[0004] In the known method, described above, the data rate of the communication uses a fallback scheme in the event of presence of interference. The data rate is reduced as this provides more robustness against background interference and channel degradation by signal reflection (echo's, delay spread, also known as inter symbol interference ISI).

[0005] However, when using a lower data rate, the transmission time of a packet will become larger. Such a larger transmission time will result in a higher probability that the transmission of the packet will be exposed to interference from periodical transmissions at the same frequency, e.g. from the above mentioned radio systems and unintentional radiators, leading to loss of the packet sent. The fall back scheme will therefore be counter productive in the presence of periodic or intermittent interference.

[0006] Another method of providing a more robust system for data communication is the use of fragmentation. Packets of data are fragmented in shorter duration frames, which are assembled to the original packet at the receiving device. This also provides robustness against interference and degradation of the data communication channel.

[0007] Using fragmentation will shorten the transmission time, but will not provide a more robust transmission with respect to background interference, echo and ISI, as these are continuous interference sources and the influence of these interferences is greatly dependent on the data rate, as explained above. Also, fragmentation will lead to more overhead needed to transmit a complete data packet, thereby reducing the throughput percentage of the system.

[0008] The object of the present invention is to provide a communication method that is more robust with respect to all kinds of interference than the methods described above.

[0009] This object is achieved by providing a method for communicating at least one packet of data with a predetermined packet size over a communication channel from a transmitter to a receiver, the transmitter having a memory for storing a common set of data rates, the method comprising the steps of fragmenting the at least one packet into a number of frames with a predetermined frame size by the transmitter, automatically selecting a combination of frame size and one of the common set of data rates by the transmitter such that the transmission time of each of the frames is limited to a predefined value, and transmitting each frame over the communication channel by the transmitter.

[0010] The method according to the present invention has the advantage that the possibility of periodic interference and transmission of a frame occurring at the same time is limited to a predefined value, thus resulting in a greater chance of successful transmission of data packets.

[0011] In an embodiment of the method according to the present invention, the predefined value of frame transmission time is determined by characteristics of interference in the communication channel. The predefined value of transmission time may be selected based on the expected interference characteristics. Alternatively, a measurement of interference present in the communication channel may be used for selecting a predefined value of frame transmission time.

[0012] In a further embodiment, the combination of frame size and data rate is changed dependent on the condition of the communication channel. This may be based on expectation or measurement of the communication channel condition. In a preferred embodiment, the condition of the communication channel is determined based on success of transmission of each of the frames. After failure of transmitting a packet, a lower data rate (combined with a certain fragmentation size) may be selected, and after a number of successful transmissions, it may be assumed that the channel condition allows a higher data rate (combined with a larger frame size, or no fragmentation at all).

[0013] In an embodiment according to the present invention, the success of transmission of each of the frames is determined after a predetermined number of retries. When a data frame has been sent over the communication channel from a first device to a second device, the second device should acknowledge receipt of the data frame, within a specified time period. When an acknowledge message is not received by the first device within the specified time

period, the first device may retransmit the same data frame. In implementations of the IEEE 802.11 standard, the number of retries allowed is in general limited. Only after not receiving a specified number of acknowledge messages, the method will change the combination of data rate and fragmentation size.

[0014] When using wireless LAN communication according to the IEEE 802.11 standard (including extensions 1 la and 11b), the set of common data rates is 11 Mbit/s; 5.5 Mbit/s; 2 Mbit/s and 1 Mbit/s. For a typical maximum payload format in present wireless LAN networks with an Ethernet backbone, the typical packet size is 1500 byte. The preferred set of frame sizes comprises 1500 bytes; 750 bytes; 500 bytes; 256 bytes and 128 bytes.

[0015] In the presence of microwave ovens, the predefined value of the transmission time is 4.5 msec. This will limit the probability that a data frame sent by the first device experiences broadband interference from the microwave oven (5-8 msec bursts every 16 or 20 msec) to a very low value.

[0016] In the presence of Bluetooth systems, the predefined value of the transmission time is 1.5 msec. This will limit the probability that a data frame sent by the first device experiences interference from the Bluetooth transmitters, which radiate in 0.366 msec bursts every 3.75 msec on one specific frequency.

[0017] In a second aspect, the present invention relates to a device for receiving or transmitting at least one packet of data with a predetermined packet size over a communication channel between the device and a second device, the device comprising a processor and memory means connected to the processor for storing a common set of data rates, the processor being arranged to fragment the at least one packet into a number of frames with a predetermined frame size, automatically select a combination of frame size and one of the common set of data rates such that the transmission time of each of the frames is limited to a predefined value, and transmit each frame over the communication channel.

[0018] The method according to the present invention may be implemented in such a device, the device being part of an apparatus transmitting data packets, e.g. in the medium access control chipsets of a wireless LAN network adapter card.

[0019] In a further aspect, the present invention relates to a computer program comprising computer readable instructions, which comprise method steps for controlling a transmitter communicating at least one data packet with a predetermined packet size over a communication channel, the transmitter having memory means for storing a common set of data rates, by fragmenting the at least one packet into a number of frames with a predetermined frame size by the transmitter, automatically selecting a combination of frame size and one of the common set of data rates by the transmitter such that the transmission time of each of the frames is limited to a predefined value, and transmitting each frame over the communication channel by the transmitter. The computer program may further comprise the method steps according to one of the claims 2 through 10. Also, the present invention relates to a data carrier provided with a computer program according to claim 13 or 14.

[0020] The present invention will now be described in more detail with reference to exemplary embodiments, with reference to the accompanying drawings, in which:

   Fig. 1a and 1b show network situations in which the method according to the present invention may be implemented;
   Fig. 2 shows a data packet or frame structure according to the IEEE 802.11 standard; and
   Fig. 3 shows a diagrammatic view of a device according to an embodiment of the present invention.

[0021] The present invention will be discussed in relation with a specific application of data communication between a first device and a second device using a communication channel, e.g. wireless LAN communication using the IEEE 802.11 standard for wireless systems operating in the 2.4-2.5 GHz industrial, scientific and medical (ISM) band.

[0022] Fig. 1a shows a network situation in access point based networks, in which the method according to the present invention may be implemented. A number of stations 2, or data communication devices, in a cell or group 4 can communicate only directly to an access point 6, e.g. via a wireless connection 3. The access point 6 forwards messages to a destination station 2 within the same cell 4, or through a wired connection 5 to another access point 6 in a further cell 8. From the further access point 6, the messages finally arrive at the destination station 2. Fig. lb shows an ad-hoc network, in which the stations 2 communicate on a peer-to-peer level via direct communication channels 3. Both the stations 2 and the access points 6 are able to communicate bi-directionally over the communication channel 3. Most of the communication channels 3 may be formed by a wireless connection between multiple stations 2 or between a station 2 and an access point 6, as described above. Alternatively, the communication channel 3 may be implemented as a wired connection, e.g. between two access points 6.

[0023] Fig. 2 shows a typical structure 10 of a data packet or data frame according to the IEEE 802.11 wireless LAN standard. A transmission of a data packet or frame 11 is preceded by a DCF (distributed coordination function) inter frames spacing, DIES, 13. The data packet or frame 11 comprises a physical layer overhead 14, a.o. for synchronisation purposes, a medium access control (MAC) header 15, and the actual data payload 16. After receipt of the data packet 11, the receiving device will wait a predetermined period, or single inter frame spacing SIFS 17, before sending an

acknowledge frame 12 to the first device. The acknowledge frame 12 also comprises a physical layer overhead 18, a. o. for synchronisation purposes, and a MAC overhead 19.

[0024] The ISM band can be used world-wide and allows unlicensed operation for spread spectrum systems. The IEEE 802.11 standard focuses on the medium access control (MAC) layer and physical layer (PHY) protocols for access point based networks and ad-hoc networks.

[0025] The IEEE 802.11 standard supports direct sequence spread spectrum (DSSS) with differential encoded BPSK and QPSK, frequency hopping spread spectrum (FHSS) with Gaussian frequency shift keying (GFSK) and infrared with pulse position modulation (PPM). The three physical layers (DSSS, FHSS and infrared) are all based on bit rates of 2 and 1 Mbit/s. Extensions are being proposed for higher bit rates for the various physical layers, extension 11b being directed at DSSS providing bit rates of 5.5 and 11 Mbit/s and extension 11a being directed at orthogonal frequency division multiplexing (OFDM) providing bit rates in the range of 6 to 54 Mbit/s in the 5 GHz band.

[0026] The IEEE 802.11 standard allows interoperability between compatible physical layers as the medium access control layer allows use of carrier sense multiple access with collision avoidance (CSMA/CA). Also, all directed data traffic uses immediate positive acknowledgement (through an acknowledge frame 12, ACK) and a retransmission is scheduled by the sender if no ACK frame 12 is received. The MAC layer of IEEE 802.11 defines special functional behaviour for fragmentation of packets. ·

[0027] As the 2.4-2.5 GHz ISM band provides an unlicensed spectrum, operation of radio systems in this band can be subject to interference from other radio systems and unintentional radiators. In the ISM band, radio systems, such as Bluetooth systems and RF ID systems (radio frequency identification tag and labelling systems), and also unintentional radiators, such as microwave ovens, are operating.

[0028] ·According to the IEEE 802.11 standard, it is possible to use a fallback in data rate when packets are lost after a few attempts by retransmitting the packets, to provide more robustness against background interference and channel degradation by signal reflection, such as echo's and or delay spread (also referenced as inter symbol interference, ISI) caused by multipath interference. Lower data rates are more robust against these types of continuous interference, and an automatic fallback and fall forward in data rate will result in a self adjusting data rate behaviour. In non-prepublished European patent application 99302624.2, filed by applicant of the present patent application, a method for enhanced data rate control for wireless data communication is disclosed. The·method selects a data rate for a communication channel 3 between first and second devices 2 having a set of common data rates by selecting an initial data rate from the set and adjusting the data rate responsive to a change in channel conditions. This method provides an auto rate control mechanism which can determine the best usable data rate for a given channel condition. The selection of an increase or decrease in data rate can be based on whether a packet is transmitted successfully or unsuccessfully, respectively.

[0029] By lowering the data rate (automatic or otherwise), the packets will take a longer time to be transmitted. When in the communication channel 3 interference is present which exhibits a periodic nature (e.g. short duration bursts), the longer time needed to transmit a packet will result in a higher risk that the packet transmitted will be mutilated by the periodic interference, leading to possible loss of the transmitted packet.

[0030] Therefore, the fallback in data rate will be counter productive in the presence of periodic interference, e.g. from nearby Bluetooth devices, which exhibit a transmission activity during 0.366 msec bursts every 3.75 msec. Bluetooth uses a frequency hopping transmission mode, in which a transmitter is active during 0.366 msec bursts in a time slot of 0.625 msec at a single specific frequency. During the next five time slots, the transmitter has no transmission activity. The hopping scheme of Bluetooth devices results in a transmission on a single specific frequency during 0.366 msec of a 0.625 msec slot time. This is followed by transmissions in the next slot times on other frequencies from the set of 79 frequencies ($f = 2402 + k$ MHz, $k = 0...78$) according to a random-like hop pattern, and then again on the first single specific frequency.

[0031] Also in the presence of microwave ovens, the communication channel 3 may be exposed to periodic interference. Microwave ovens emit microwave energy in a frequency band of several MHz wide, in bursts of 5-8 msec during every 16 or 20 msec cycle (the 16 msec cycle being present in microwave ovens operating at 60 Hz mains, and the 20 msec cycle being present in microwave ovens operating at 50 Hz mains).

[0032] The time periods of the data packet or data frame 11 according to the IEEE 802.11 standard using direct sequence spread spectrum (DSSS) techniques will now be described. The data packet or frame 11 is preceded by a DCF (distributed coordination function) inter frame spacing 13 (DIFS) of 50 µsec, regardless of the data rate. The data packet or frame 11 starts with a physical layer overhead (PHY) 14, or preamble/header, which is also independent on the data rate used and takes 192 µsec. According to the IEEE 802.11 standard, it is possible to use a short preamble/header 14 in the high speed variants (5.5 and 11 Mbit/s) of only 96 µsec. The next block is the medium access control (MAC) overhead 15, which is dependent on the data rate used. Next, the data payload 16 is included in the structure 10, and the time thereof depends on the payload size and the data rate.

[0033] After the data payload 16, a short inter frame spacing 17 (SIFS) of 10 µsec is present and precedes an acknowledge (ACK) frame 12. This acknowledge frame 12 comprises a physical layer (PHY) overhead 18 of 192 µsec

(96 μsec in the case of short preamble/ header at high speeds) which is independent on data rate, and a medium access control overhead 19 of 112 μsec (1 Mbit/s data rate) or 56 μsec (other data rates).

[0034]   In the following table, the transmission times (in μsec) of the components of a packet of 1500 bytes are shown for different data rates. A packet size of 1500 byte is a typical maximum payload for present wireless LAN networks with an Ethernet backbone, e.g. as used for file transfer. For the higher speeds (5.5 and 11 Mbit/s) it is possible to use a short preamble/ header, as indicated by (sh.pr.) in the table.

Table 1

bit rate (MHz)	DIFS (µsec)	DATA (µsec)			SIFS (µsec)	ACK (µsec)		total (µsec)	throughput (Mbit/s)	Throughput percentage
		PHY preamble/header	MAC overhead	data		PHY preamble/header	MAC overhead			
1	50	192	272	12000	10	192	112	12828	0.94	93.5
2	50	192	136	6000	10	192	56	6636	1.81	90.4
5.5	50	192	49	2182	10	192	56	2732	4.39	79.8
11	50	192	25	1091	10	192	56	1616	7.43	67.5
5.5 (sh.pr.)	50	96	49	2182	10	96	56	2542	4.72	85.8
11 (sh.pr.)	50	96	25	1091	10	96	56	1424	8.43	76.6

[0035] For fragmented data packets 11, the same structure is used, but the size of the data payload 16 becomes smaller, and hence the total transmission time of the data frame. Because of all overhead parts in the structure 10, the total transmission time of the original data packet will naturally increase.

[0036] According to the present invention, the medium access control scheme provides a fallback (resp. fall forward) in bit rate in combination with fragmentation of packet data payload in frames in order to limit the transmission time. Preferably, the limit of frame transmission time is configurable and selected from a set of alternatives. The recommended setting may be based on the type and characteristic of the interference that can be expected. Alternatively, means may be provided to measure the characteristics of interference that is present in the communication channel 3.

[0037] In an environment where IEEE 802.11 communication systems 2, 6 operate collocated with Bluetooth systems, the set of alternative combinations of data rate and frame size is preferably as follows:

11 Mbit/s; no fragmentation;
5.5 Mbit/s; fragmentation in frames of maximum 750 bytes;
2 Mbit/s; fragmentation in frames of maximum 256 bytes;
1 Mbit/s; fragmentation in frames of maximum 128 bytes.

[0038] This will result in a maximum frame transmission time of about 1.5 msec or less and will make the IEEE 802.11 communication more robust against Bluetooth interference, as this interference occurs in active periods of 0.366 msec each 3.75 msec on one single frequency.

[0039] In an environment where IEEE 802.11 communication systems 2, 6 operate with microwave ovens operating nearby systems, the set of alternative combinations of data rate and frame size is as follows:

11 Mbit/s; no fragmentation;
5.5 Mbit/s; no fragmentation;
2 Mbit/s; fragmentation in frames of maximum 750 bytes;
1 Mbit/s; fragmentation in frames of maximum 500 bytes;

[0040] This will result in a maximum frame transmission time of about 4.5 msec or less and will make the IEEE 802.11 communication more robust against interference from nearby microwave ovens, as this interference occurs in active periods of 5-8 msec each 16 (60 Hz operation) or 20 msec (50 Hz operation).

[0041] Lowering the transmission time for a data frame to much lower levels (e.g. by using a higher data rate or higher degree of fragmentation) will not drastically further reduce the probability that transmission of a data frame will be interfered by the periodic or intermittent interfering signals.

[0042] The fallback in data rate in combination with fragmentation of the data packet into data frames may only occur for a complete data packet, as the IEEE 802.11 standard does not allow change of fragmentation size or data rate during transmission of a data packet which is fragmented into smaller data frames. Change of fragmentation size during transmission of a number of data frames would disturb the defragmentation process at the receiving device. Therefore, a fallback (or fall forward) in combination of data rate and fragmentation size should only be executed at the start of transmission of the next data packet.

[0043] In normal operation according to the IEEE 802.11 standard, a retransmission will be attempted by the sending device 2, when no acknowledgement is received from the receiver after sending a data frame or packet. After a number of retries for sending the data frame or packet, it is assumed that the communication channel 3 is unsuited for transmission at that specific data rate, and a fallback option in data rate, e.g. as disclosed in non-prepublished European patent application 99302624.2, is applied to provide a communication channel 3 which is more robust. When the communication channel 3 is already being operated at its lowest data rate, a control message may be generated, indicating that the present communication channel 3 is unsuited for transmission of data packets.

[0044] In the case of intermittent or periodic interference, such as from the Bluetooth systems mentioned above, it would be advantageous to allow a larger number of retries for transmitting a data frame or packet 11. This would allow "shifting" the transmission time of the data frame or packet to the period between active interference periods, still enabling interference free transmission at the higher data rate.

[0045] The method according to the present invention thus provides an automatic selection of the combination of data rate and fragmentation size, resulting in a system which is much more robust in the presence of bursty interference. The throughput in absence of interference is not affected, as in that situation the highest data rate with no fragmentation will be selected.

[0046] In Fig. 3, a diagrammatic view is shown of a device according to an embodiment of the present invention. The device may be part of any of the stations 2 or access points 6 described with reference to Fig. la and 1b. The device comprises a microprocessor 20 functioning as a control unit of the device. The microprocessor 20 is connected to memory means 21, such as random access memory, read-only memory or non-volatile memory. The microprocessor

20 is also connected to receiver/transmitter 22, which in its turn is connected to an antenna 23. Finally, the microprocessor 20 is also connected to an interface 24, for communicating with a host device, such as a computer (not shown). According to an embodiment of the present invention, the microprocessor 20 is arranged to execute the method of the present invention as described above. The set of common data rates and the set of fragmentation packets, and the preferred combinations of data rate and fragmentation size may be stored in the memory means 21.

[0047]   The components of the device may, e.g., form part of an IEEE 802.11 wireless LAN network adapter card. Then, the microprocessor 20 may be formed by the medium access control chipset on the network adapter card.

[0048]   Above, the present invention has been illustrated with reference to a number of exemplary embodiments. However, these are given to illustrate the present invention and not to limit the scope of protection as defined by the accompanying claims.

Claims

1. Method for communicating at least one packet of data (11) with a predetermined packet size over a communication channel (3) from a transmitter (2; 6) to a receiver, the transmitter (2; 6) having a memory (21) for storing a common set of data rates, the method comprising the steps of:

   fragmenting the at least one packet into a number of frames with a predetermined frame size by the transmitter (2; 6);
   automatically selecting a combination of frame size and one of the common set of data rates by the transmitter (2; 6) such that the transmission time of each of the frames is limited to a predefined value; and
   transmitting each frame over the communication channel (3) by the transmitter (2; 6).

2. Method according to claim 1, in which the predefined value of transmission time is determined by characteristics of interference in the communication channel (3).

3. Method according to claim 1 or 2, in which the combination of frame size and data rate is changed dependent on the condition of the communication channel (3).

4. Method according to claim 3, in which the condition of the communication channel (3) is determined based on success of transmission of each of the frames.

5. Method according to claim 4, in which success of transmission of each of the frames is determined after a predetermined number of retries.

6. Method according to claim 5, in which the predetermined number of retries is at least two.

7. Method according to one of the preceding claims, in which the predefined value of the transmission time is 4.5 msec.

8. Method according to one of the claims 1 through 6, in which the predefined value of the transmission time is 1.5 msec.

9. Method according to one of the preceding claims, in which the frame size is one of a set of frame sizes comprising 1500 bytes, 750 bytes, 500 bytes, 256 bytes and 128 bytes.

10. Method according to one of the preceding claims, in which the common set of data rates comprises data rates of 11 Mbit/s; 5.5 Mbit/s; 2 Mbit/s and 1 Mbit/s.

11. Device for receiving or transmitting at least one packet of data (11) with a predetermined packet size over a communication channel (3) between the device (2; 6) and a second device (2; 6), the device (2; 6) comprising a processor (20) and memory means (21) connected to the processor (20) for storing a common set of data rates, the processor (20) being arranged to

   fragment the at least one packet into a number of frames with a predetermined frame size;
   automatically select a combination of frame size and one of the common set of data rates such that the transmission time of each of the frames is limited to a predefined value; and
   transmit each frame over the communication channel (3).

12. Device according to claim 11, in which the processor (20) is further arranged to execute the method according to one of the claims 2 through 10.

13. Computer program comprising computer readable instructions, which comprise method steps for controlling a transmitter (2; 6) communicating at least one data packet (11) with a predetermined packet size over a communication channel (3), the transmitter (2; 6) having memory means (21) for storing a common set of data rates, by:

fragmenting the at least one packet into a number of frames with a predetermined frame size by the transmitter (2; 6);

automatically selecting a combination of frame size and one of the common set of data rates by the transmitter (2; 6) such that the transmission time of each of the frames is limited to a predefined value; and

transmitting each frame over the communication channel (3) by the transmitter (2; 6).

14. Computer program according to claim 13, further comprising the method steps according to one of the claims 2 through 10.

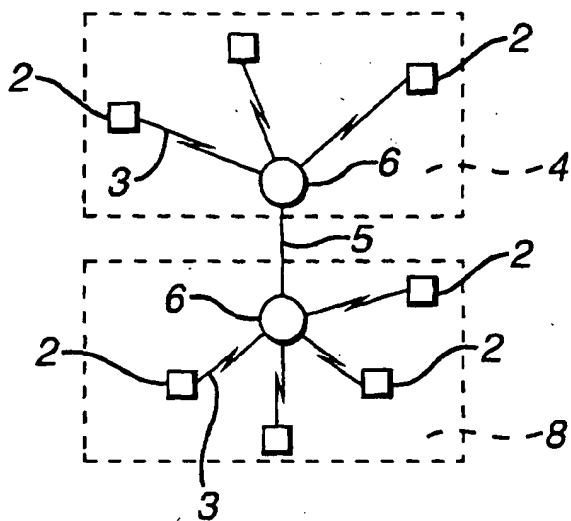**15.** Data carrier provided with a computer program according to claim 13 or 14.
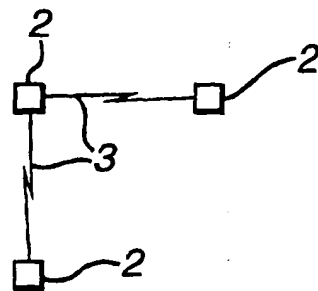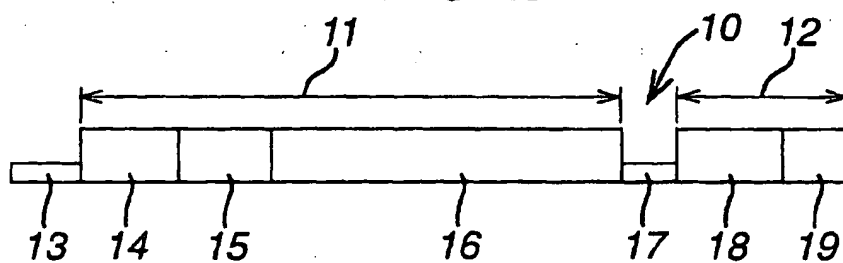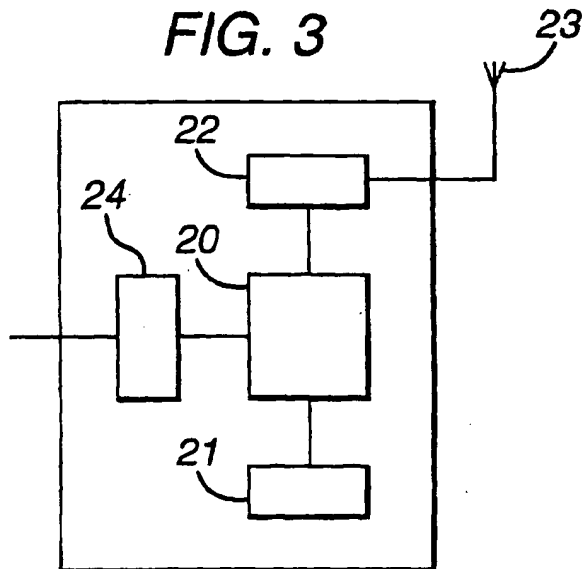
FIG. 1a

FIG. 1b

FIG. 2

FIG. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 00 30 0343

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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Y	* column 22, line 36 - column 22, line 67 *	4-6	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 July 2000	Blanco Cardona, P

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 00 30 0343

This annex lists the patent family members relating to the patent documents cited in the above–mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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